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New host record of *Doggerella chasanica* (Hymenoptera, Braconidae, Braconinae) as a larval parasitoid of the serious forest pest *Monochamus alternatus* (Coleoptera, Cerambycidae) in Korea

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Abstract

South Korea has been affected by pine wilt disease (PWD), with the vectors *Monochamus alternatus* Hope, 1842 and *M. saltuarius* Gebler, 1830 (Coleoptera: Cerambycidae) and PWD has expanded severely in southeastern South Korea since the late 2010s. In the pursuit of environmental-friendly pest management, we searched for potential natural enemies of *M. alternatus*. In 2019, we reared specimens of *M. alternatus* and confirmed that members of *Doggerella* (*Lelejobracon*) *chasanica* (Tobias, 2000) eclosed from them, for the first time. The average parasitism rate for *D.* (*L.*) *chasanica* was 4.2%, with a maximum parasitism rate of 5.9% in the sites investigated. Herein, we provide information on how we collected and reared *M. alternatus* along with a brief biological note, as well as re-description and a brief biological note of the parasitoid *D. chasanica*.

Keywords

Biology, COI DNA barcode, forest disease, invasive species, longhorn beetle, parasitoid, pine diseases

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Introduction

Pine wilt disease (PWD) is caused by the pine wood nematode (PWN), *Bursaphelenchus xylophilus* (Steiner and Buhrer 1934) and requires a vector for transmission, as the nematode is unable to move between pine trees on its own. The vectors of PWN belong to the genus *Monochamus* Dejean, 1821 (Coleoptera: Cerambycidae). Five species are recorded in East Asia (*M. alternatus* Hope, 1842, *M. grandis* Waterhaus, 1881, *M. luxuriosus* Bates, 1873, *M. saltuarius* Gebler, 1830, *M. subfasciatus* Bates, 1873) (Naves et al. 2005).

In South Korea, PWD was first reported from Busan in Korea in 1988 (Yi et al. 1989), and on Jeju Island in 2004 (Korea Forest Research Institute 2011). Two cerambycid species, *M. alternatus* and *M. saltuarius*, are known as the vectors of PWD. Particularly, *M. alternatus* is the more predominant vector of PWD on the Korea peninsula and the largest island in Korea, Jeju Island (Kwon et al. 2006). *Pinus densiflora* Siebold & Zucc., which occupies the largest forested area in South Korea and has been widely restored since the 1970s, serves as the main food source for *M. alternatus* (Choung et al. 2020). Given this, understanding tri-trophic interactions among *P. densiflora*, *Monochamus* spp., and parasitoids is crucial for reducing PWD.

Jeju Island is ecologically and geologically significant in Korea. As a volcanic island, it features a unique volcanic landscape and distinct flora and fauna, many species of which are endemic. Due to the importance, Jeju was designated as a UNESCO world natural heritage site in 2007 (UNESCO 2007). Despite ongoing management efforts, Jeju has continued to officially report damage caused by PWD (Korea Forest Service 2024). Researchers have been developing various ecologically sustainable methods to prevent and mitigate damage caused by PWD (Jeong et al. 2015; Park 2022). Among these, studies on the natural enemies of vectors have been conducted intermittently (Hong et al. 2008; Jang et al. 2019; Kim et al. 2022). Particularly in laboratory settings, *Sclerodermus harmandi* (Buysson, 1903) (Hymenoptera: Bethylidae) exhibited high oviposition and eclosion rates on larvae of *M. saltuarius*. For *M. alternatus*, the oviposition rate on host pupae was high but relatively low on larvae (Hong et al. 2008).

Our study confirmed that *Doggerella* (*Lelejobracon*) *chasanica* (Tobias, 2000) parasitizes *M. alternatus* immatures, representing a new host record for *D.* (*L.*) *chasanica*. This work presents the first investigation of natural enemies of *M. alternatus* on Jeju Island and describes the collecting and rearing methods used to find parasitoids. Additionally, we provide a brief biological note on *M. alternatus* and *D.* (*L.*) *chasanica*, contributing to the broader understanding of their ecological interactions.

Methods

Study sites and sessions

Three study sites comprising *Pinus densiflora* Siebold & Zucc. infested by PWD were selected for this research (Fig. 1). The detailed characteristics of the study sites and sessions are provided (Table 1). Considering the activity period of *M. alternatus* on Jeju Island

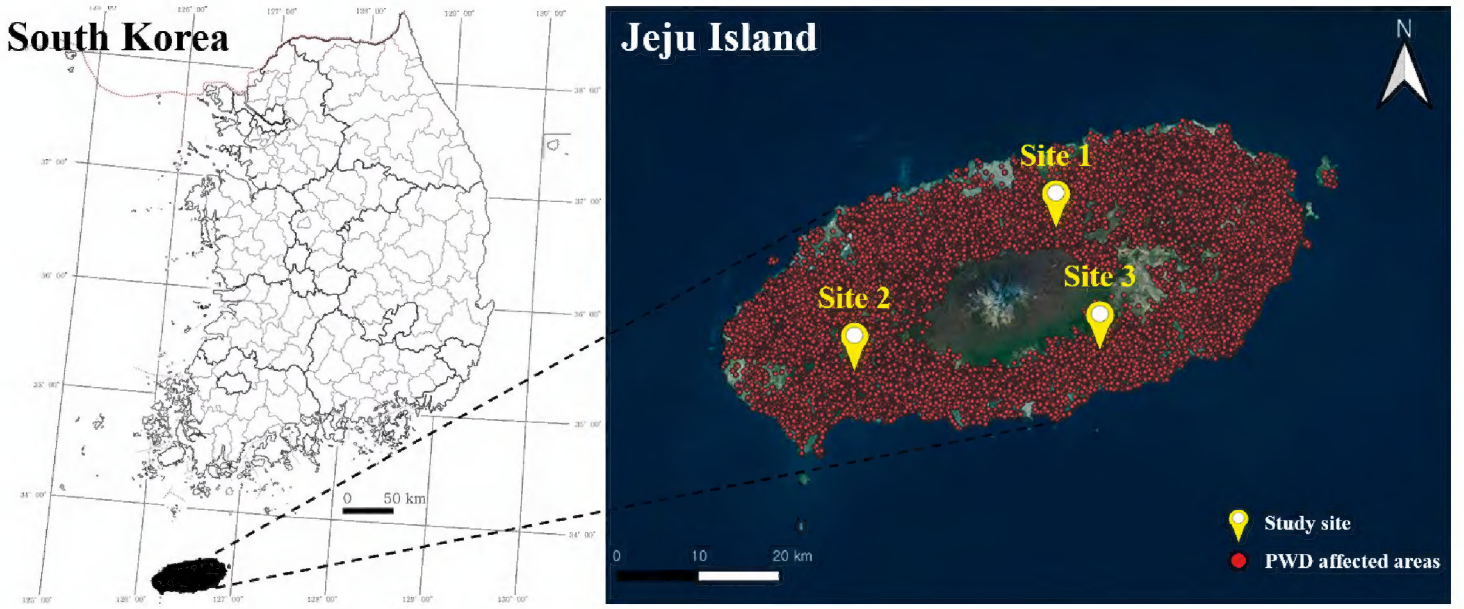

Figure 1. Three study sites affected by PWD on Jeju Island, South Korea.

Table 1. Detailed characteristics of the study sites (Jeju Island, South Korea).

Factor	Level		
Location	Site 1 (33°26'21.05"N, 126°34'45.59"E)	Site 2 (33°19'25.28"N, 126°17'18.48"E)	Site 3 (33°19'7.92"N, 126°36'55.35"E)
Survey year	2019		
Session	1st (June 4th wk), 2nd (July 1st wk), 3rd (July 3rd wk)		
Forest type	Natural		
Dominated tree species	*P. densiflora*		
No. of used sentinel logs	*M. alternatus*: 135		
DBH-class (cm)	18–28		
Crown density	High		
Age-class (year)	40–50		

(Kwon et al. 2019), we conducted three sessions at two-week intervals, from the fourth week of June to the third week of July in 2019. Fifteen sentinel logs per session were used in each site, and a total of 135 logs were employed throughout the experiment (Table 1).

Installation of sentinel log and rearing

Identifying the natural enemies of *M. alternatus* required height-specific surveys to locate parasitoids of its eggs or larvae. *M. alternatus* females primarily oviposit at approximately six meters on pine trees but can lay eggs at heights ranging from 0–12 m (Futai et al. 1994). To account for this variation, we conducted field surveys and installed traps at different heights. The sentinel logs were installed following the method of Kim et al. (2022) (Fig. 2A). To install the logs, we utilized ropes (thickness: 5 mm), sandbags (weight: 340 g), and a slingshot (sling shot / length: 240 cm) to shoot the ropes over the branches in the tree canopy (Fig. 2B).

Three *P. densiflora* trees were selected with a distance of 20 m between each tree. To investigate the preferred height of the natural enemies, we attached the sentinel logs to the rope using wire (thickness: 2 mm) at 2 m intervals (0, 2, 4, 6, and 8 m). We then

Figure 2. Sentinel log installation process using a slingshot and rope in study site **A** preparation of sentinel logs that include eggs of *M. alternatus* with a rope to fix the sentinel logs **B** a rope tied to a sandbag to shoot up a pine tree branch with a slingshot **C** pulled the rope from the opposite side and installed at the desired height **D** after 2 weeks, dissection of sentinel logs using small knife in the laboratory.

pulled the ropes from the opposite side to install the sentinel logs at the desired heights (Fig. 2C). After two weeks, the sentinel logs were collected, and bark was peeled and dissected using a Swiss army knife in the lab to check whether *M. alternatus* larvae were parasitized. To prevent *M. alternatus* larvae and parasitoid larvae under the bark from dying, we removed the bark as gently as possible without damaging the larvae, ensured the logs remained moist during dissection, and minimized exposure to dry air (Fig. 2D).

Unparasitized *M. alternatus* larvae were separated and preserved in 99% ethanol, while parasitized *M. alternatus* larvae were transferred to small plastic cups (4.5Ø / 30 ml) and reared at room temperature (25 ± 1 °C) until they emerged as adults (Fig. 3A, B). Parasitoid larvae were observed daily, and their condition and eclosion dates were recorded.

Morphological analyses

Stereomicroscopes (Leica M205A Stereozoom & Leica S9E; Leica Microsystems, Solms, Germany) were used to examine specimens, and Leica M205A Stereozoom was used to capture images of the diagnostic characteristics of the parasitoids and the head capsules of parasitized *M. alternatus* larvae. LAS software (version 4.1.0, Leica Microsystems, Switzerland) was used for image stacking. Adobe Photoshop CS6 and Adobe Photoshop 2024 (Adobe Systems Incorporated, San Jose, United States of America) were used to edit stacked images and measure braconid morphometric characters. The head capsule width of *M. alternatus* larvae was measured to determine their instar stages, following Go et al. (2019). In the description of species, the numbers in parentheses represent the sizes of body parts, with mm as the unit of length. The morphological terms are based on Sharkey and Wharton (1997), and terminology for sculpturing follow Harris (1979).

Molecular analyses

Genomic DNA was extracted from legs or metasoma of parasitoid specimens using the DNeasy Blood and Tissue Kit (QIAGEN, Hilden, Germany). Polymerase chain reaction (PCR) was performed, and the 658 bp fragment of the mitochondrial cytochrome *c* oxi-

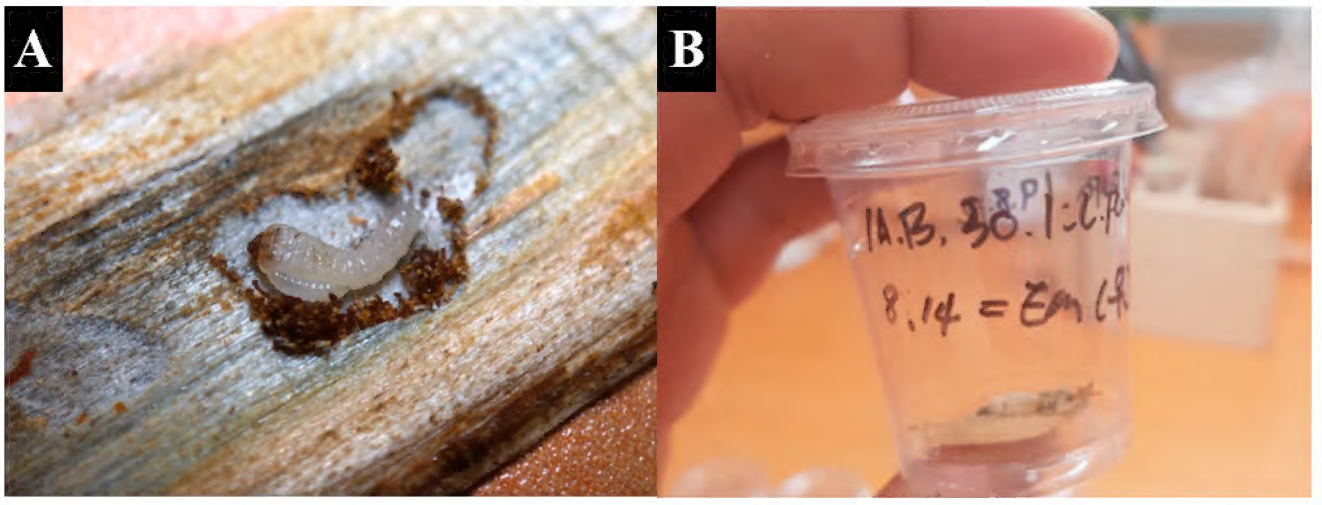

Figure 3. The process of identification of parasitized host larvae and rearing parasitoids in sentinel logs. **A** Debarking of sentinel logs to collect intact or parasitized host larvae **B** rearing parasitoids in small breeding cups.

dase subunit I (COI) gene was targeted using the primer set LepF1 and LepR1 (Hebert et al. 2004). Each 25 µl PCR reaction contained 12.5 µl of DreamTaq Green PCR Master Mix (2X) (Thermo Scientific), 3 µl of template genomic DNA, 7.5 µl of ddH_2O, and 1.0 µl of each primer at a concentration of 10 µM. The PCR protocol consisted of an initial denaturation at 94 °C for 3 min, followed by 5 cycles of 94 °C for 30 s, 45 °C for 30 s, and 72 °C for 1 min; 35 additional cycles of 94 °C for 30 s, 51 °C for 30 s, and 72 °C for 1 min; and a final extension at 72 °C for 7 min. Amplification success was confirmed by visualizing crude PCR products on 1.0% agarose gels. Purification and sequencing were conducted by Macrogen (Sejong, South Korea) using the 3730xl DNA Analyzer (Applied Biosystems, Foster City, CA, USA). Sequence data were processed via Geneious Prime 2025.0.1 (https://www.geneious.com). Primer regions were trimmed, and sequences were edited and assembled using de novo assembly. The final consensus sequence was generated by combining the sequences of multiple individuals, following the method of Sharkey et al. (2021).

Specimen information

The specimens used for this work will be deposited in the Korea National Arboretum (KNA).

Results

Parasitism of *M. alternatus* by *D.* (*L.*) *chasanica* and biological notes

Monochamus alternatus was confirmed as a new host record of *Doggerella* (*Lelejobracon*) *chasanica* from this study. Members of *D.* (*L.*) *chasanica* parasitize the 2nd and 3rd instar larvae of *M. alternatus* (average head width: 1.6 ± 0.3 mm), with an average parasitism rate of 4.2 % and a maximum parasitism rate of 5.9 % in the sites on Jeju Island in 2019 (Table 2). The parasitoid was confirmed to be a solitary ectoparasitoid, spinning a cocoon near remnants of the host larva after feeding. The pupal stage of *D.* (*L.*) *chasanica* was confirmed as 11.6 ± 1.9 days at 25 °C days on *M. alternatus* (Table 2).

Table 2. Biological information of parasitoids from *M. alternatus* on Jeju Island.

Site	Session	Parasitoids #	Height of sentinel log	Head capsule size of *M. alternatus* (Laval instar)		Pupa period in 25 °C (day)		Parasitism rate (%) = (number of parastized host larvae / total number of host larvae) × 100		Sex of parasitoid
				Individuals	average	Individuals	average	Individuals	average	
Site 2	1st (June 4th wk)	1	2 m	1.6 mm (3rd)	1.6 ± 0.3	15	11.6 ± 1.9	5.9%	4.2%	Female
		2	2 m	1.5 mm (3rd)		14				
		3	6 m	1.1 mm (3rd)		10				
		4	4 m	1.2 mm (2nd)		10				
		5	8 m	1.7 mm (3rd)		10				
	2nd (July 1st wk)	6	6 m	1.9 mm (3rd)		11		2.4%		
		7	6 m	2.0 mm (3rd)		11				

The members of *M. alternatus* exhibit the highest occurrence rate in Jeju Island between mid-June and early July, and *D.* (*L.*) *chasanica* was collected during this period as well. The braconid parasitoids were collected only at site 2 from mid-June to mid-July (session: 1st and 2nd). They parasitized *D.* (*L.*) *chasanica* at heights from 2 to 8 m (Table 2).

Taxonomy

Genus *Doggerella* Quicke, Mahmood & Papp, 2011

Doggerella Quicke, Mahmood & Papp, 2011: 2.

Type species. *Doggerella turneri* Mahmood, Quicke & Papp, 2011.

Subgenus *Lelejobracon* Samartsev, 2016

Doggerella (*Lelejobracon*) *chasanica* in Samartsev, 2016: 124.

Type species. *Bracon chasanicus* Tobias, 2000.

***Doggerella* (*Lelejobracon*) *chasanica* (Tobias, 2000)**
Fig. 4A–F

Bracon chasanicus Tobias, 2000, Belokobylskij and Tobias 2000: 148.
Doggerella (*Lelejobracon*) *chasanica* in Samartsev 2016: 124.
Bracon bitumor Papp, 2018: 26.
Bracon planitibiae Yang, Cao & Gould, 2019, in Cao et al. 2019: 430.
Doggerella (*Lelejobracon*) *chasanica* (Tobias, 2000), in Samartsev 2019: 54.
Doggerella (*Lelejobracon*) *chasanica* (Tobias, 2000), in Samartsev et al. 2024: 198.

Material examined. Non-type South Korea • 5♀; Hangyeong-myeon, Jeju-si, Jeju-do, Korea; 33°19'25.28"N, 126°17'18.48"E; 17.VI.–2.VII. 2019; Moo-Sung Kim (Korea National Arboretum) leg.; Host insect: *Monochamus alternatus*. • 2♀; Hangyeong-myeon, Jeju-si, Jeju-do, Korea; 33°19'25.28"N, 126°17'18.48"E; 1–16.VII.2019; Moo-Sung Kim (Korea National Arboretum) leg.; Host insect: *M. alternatus*.

Diagnosis. Samartsev (2016) transferred *Bracon chasanicus* Tobias, 2000 to *Doggerella* Quicke, Mahmood & Papp, 2011, establishing the subgenus *Lelejobracon* and recognizing *D.* (*L.*) *chasanica*as the only *Doggerella* (*Lelejobracon*) species recorded from Russia. Later, Samartsev (2019) synonymized *Bracon planitibiae* Yang, Cao & Gould, 2019 and *B. bitumor* Papp, 2018 with *D.* (*L.*) *chasanica*. Regarding the subgenus, as discussed in detail by Samartsev (2016), *Lelejobracon* is easily distinguished from *Doggerella* s. str., which is restricted to the Afrotropical region, by its smooth and polished metasoma (Fig. 4C).

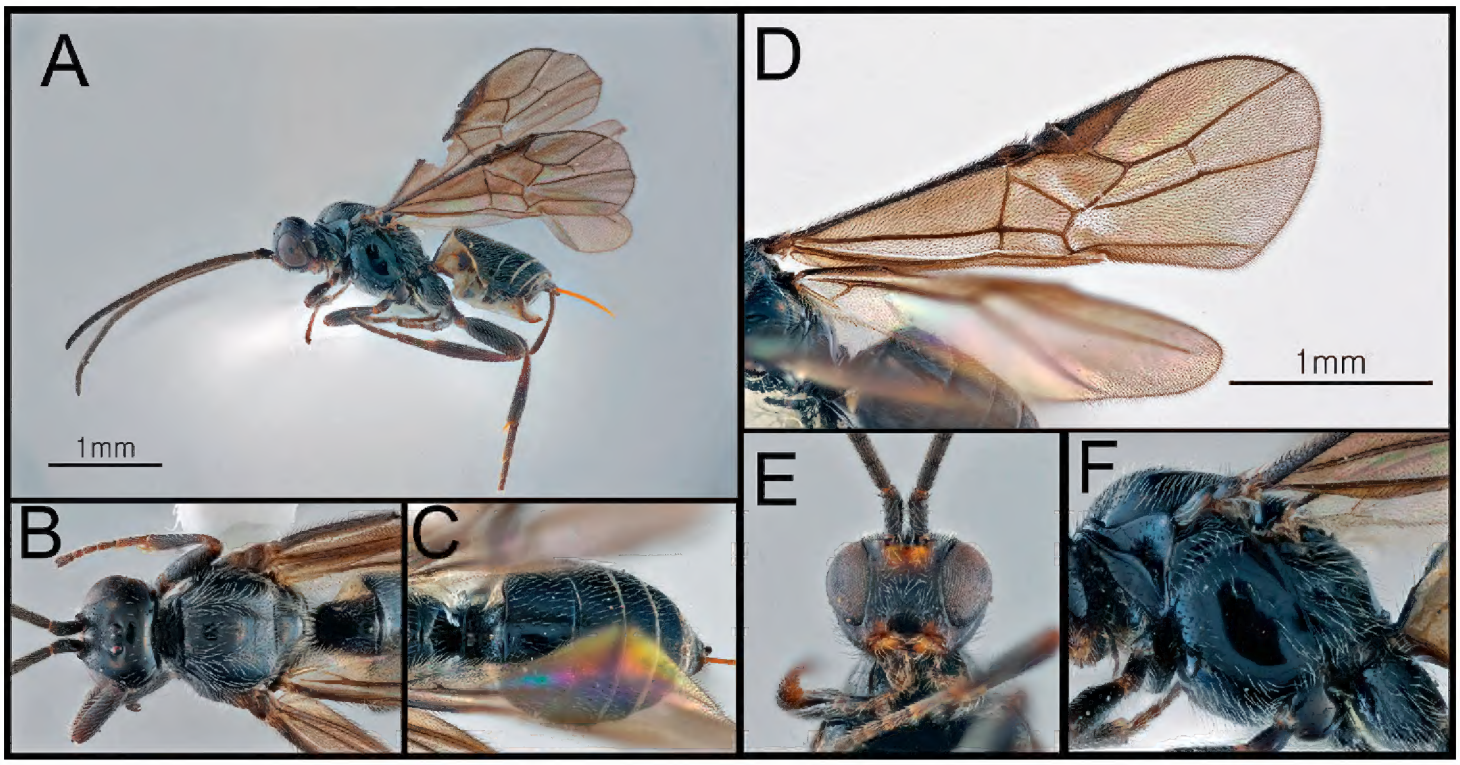

Figure 4. *Doggerella* (*Lelejobracon*) *chasanica*, female, non-type, collected from Korea **A** lateral habitus **B** dorsal head, mesosoma, and tergum 1 **C** propodeum and metasoma **D** wings **E** anterior head **F** lateral mesosoma.

Molecular data. The first COI DNA barcodes for *Doggerella* (*Lelejobracon*) *chasanica* were successfully obtained from specimens collected in Korea. The COI barcodes from two individuals were identical.

Consensus COI sequence (658 bp; GenBank accession numbers: PV169210, PV169211);

TATATTATATTTTTTTTTTGGTATTTGATCAGGAATTTTAGGTTTATC-
TATAAGAATAATTATTCGATTAGAATTAGGAATACCAGGAAGTTTATTAG-
GTAATGATCAAATTTATAATAGTATAGTAACTGCTCACGCATTTGTAATA-
ATTTTTTTTATAGTTATACCAGTAATATTAGGTGGGTTTGGAAATTGAT-
TAATTCCTTTAATATTAGGGGCTCCTGATATAGCTTTCCCTCGAATA-
AATAATATAAGATTCTGATTACTTATTCCTTCATTAATTTTATTAATTTTA-
AGAAGAATTTTAAATGTTGGTGTTGGAACTGGATGAACAGTTTATCCTC-
CATTATCTTCTTCTTTAGGCCATAGAGGTATATCTGTTGATATAGC-
TATTTTTTCTTTACATTTAGCTGGAGCTTCATCAATTATAGGTTCAAT-
TAATTTTATTACTACTATTTTTAATATAAAATTAAATATTTTAAAATTAG-
ATCAAATATCTTTGTTTATTTGATCAATTTTAATTACAACAATTTTAT-
TACTTTTATCTTTACCGGTATTAGCTGGTGCTATTACTATATTATTAACA-
GATCGAAATTTTAATACATCATTTTTTGATTTTGCTGGTGGAGGAGA-
TCCTGTTTTATTTCAACATTTATTT

Redescription. The species was well-described by Samartsev (2016) and Samartsev et al. (2024). Most characters observed in the current study align with those described by Samartsev (2016) and Samartsev et al. (2024). However, we provide this redescription to include additional characters not mentioned in the previous studies and to provide a description with terminology that readers familiar with terminology used by Sharkey and Wharton (1997), particularly regarding wing vein terminology.

Body length 2.6 mm. Antenna length: 2.1 mm. Fore wing length 2.8 mm. Hind wing length 2.2 mm.

Head. Antenna with 24–27 segments. 1st flagellomere as long as 2nd flagellomere (Fig. 4A, E). Vertex smooth and polished, sparsely setaceous (Fig. 4B). Frons entirely variolate. Face mostly variolate, width 1.5 × longer than its height (0.59:0.39). Anterior ocellus 0.7 × longer than distance between posterior ocelli (0.04:0.06). Eye sparsely setose; median width of eye 0.7 × longer than its height (0.24:0.35) in lateral view and 1.7 × longer than median width of gena in lateral view (0.24:0.14). Distance between anterior tentorial pits 0.15 mm. Hypoclypeal depression deep, 1.4 × longer than wide. Malar space 0.5 × longer than basal width of mandible (0.05:0.11) and 1/6 of eye height in anterior view (0.05:0.31).

Mesosoma. Mesosoma 1.5 × longer than maximum height in lateral view (1.08:0.7) (Fig. 4F). Mesoscutum entirely polished with long setae, basally punctate (Fig. 4B). Notauli weakly present, not meeting posteriorly (Fig. 4B). Scutellar sulcus straight, short, and finely crenulate. Scutellum entirely polished with long setae. Pronotum polished. Mesopleuron mostly smooth and polished; relatively bare medially (Fig. 4F). Metapleuron entirely with long setae (Fig. 4F). Propodeum entirely smooth and polished, anteriorly setose, 0.8 × longer than its maximum width (0.31:0.39).

Legs. Fore femur 0.7 × longer than fore tibia (0.34:0.48). Basal spur on fore tibia 0.5 × longer than fore basitarsus. Fore basitarsus 0.8 × longer than combined length of second to fourth tarsomeres (0.17:0.22). Mid tibia as long as mid femur (0.41:0.41). Basal spur on mid tibia 0.4 × longer than mid basitarsus (0.09:0.23). Mid basitarsus as long as combined length of second to fourth tarsomeres (0.23:0.24). Hind femur 0.8 × longer than fore tibia (0.6:0.8) Basal spur on hind tibia 0.4 × longer than hind basitarsus (0.11:0.3). Hind basitarsus 0.9 × longer than combined length of second to fourth tarsomeres (0.3:0.34).

Wings. Fore wing length 2.7 × longer than its width (2.82:1.05) (Fig. 4D). Pterostigma 3.2 × longer than its width (0.58:0.18). 1RS as long as (RS+M)b vein. (RS+M)b vein present, 0.2 × longer than 2RS (0.05:0.28). r 0.6 × longer than 2RS (0.16:0.28). 3RSa 1.8 × longer than r (0.29:0.16). 3RSb reaching wing margin as a tubular vein. r-m present as tubular vein medially. 2nd submarginal cell trapezoid seemingly with two right angles apically (Fig. 4D). 3M reaching wing margin as a tubular vein. 3CU reaching wing margin as a tubular vein. Apical angle between mc-u and 2Cua approximately 120°. Hind wing RS and M strongly developed, not reaching wing margin (Fig. 4D). M+CU 0.5 × longer than 1M (0.27:0.58). m-cu crossvein absent. cu-a entirely developed. 1A vein present not reaching wing margin.

Metasoma. Metasoma mostly polished and setose with long pale setae. Tergum 1 nearly rectangular (Fig. 4B); Y-shaped suture on tergum 1 present and crenulate (Fig. 4B); spiracle of tergum 1 located at basal third. Suture between tergum 2 and tergum 3 deep and finely granulose (Fig. 4C). Tergum 2 1.6 × longer than tergum 3 medially (0.34:0.22); spiracle of tergum 2 located at basal third. Setose part of ovipositor sheath as long as hind femur and 0.8 × longer than hind tibia (0.6:0.8). Ovipositor slightly curved.

Color. Body mostly polished black. Setae on body whitish to ivory. Antenna mostly dark brown; annellus brown. Face dorsomedially bright brown to yellow. Malar

space brown. Mandibles mostly yellow. Wings mostly slightly infuscate. Pterostigma entirely brown. Legs mostly brown. Fore tarsus bright brown. Trochantelli mostly yellow. Tibial spurs yellow. Mesosternum mostly ivory. Ovipositor yellow.

Host insects. *Anoplophora glabripennis* (Motschulsky, 1853), *Monochamus alternatus* Hope, 1842 (new host record).

Distribution. China, Korea (GG, GN, Jeju (new record)), Russia (Far East).

Discussion

Doggerella (*Lelejobracon*) *chasanica* was first described as a new species of ectoparasitoid of larvae of *Anoplophora glabripennis* (Motschulsky, 1853) (Coleoptera: Cerambycidae) by Cao et al. (2019) from China. We report *D.* (*L.*) *chasanica* also attack larvae of *Monochamus alternatus* as an additional host insect. This discovery is particularly relevant, as it suggests that *D.* (*L.*) *chasanica* could be explored as a potential biological control agent against *M. alternatus*, and consequently, may help manage the spread of pine wilt disease in Korea. Given that *A. glabripennis* is another major pest species, the parasitoid's ability to attack both *M. alternatus* and *A. glabripennis* enhances its potential as a biological control tool for invasive species. The discovery also implies that *D.* (*L.*) *chasanica* should be carefully evaluated before being considered as a viable biological control agent. Despite this broadened host range, the parasitoid still only targets two host species in China and Korea, limiting its current host range. This limited range, however, is a positive aspect for its consideration as a potential biological control agent. To assess its potential in controlling pest populations, further research is needed to understand its effectiveness across different environments and host species.

The parasitism rates against *M. alternatus* in Korea are highly similar to the parasitism rates against *A. glabripennis* investigated by Cao et al. (2019). Although the active season of *D.* (*L.*) *chasanica* overlaps with *M. alternatus*, from mid-June to early July, the parasitism rates of *D.* (*L.*) *chasanica* against *M. alternatus* were low, an average parasitism rate of 4.2 % and a maximum of 5.9 % in 2019. In Cao et al. (2019), female adults of *D.* (*L.*) *chasanica* parasitized first instar larvae of *A. glabripennis*, with an average parasitism rate of 4.0 % and a maximum of 5.9 %. These relatively low parasitism rates could indicate significant challenges when considering *D.* (*L.*) *chasanica* as a biological control agent. Low parasitism rates limit the effectiveness of parasitoid in controlling pest populations, particularly in large-scale infestations (Sint et al. 2016). This raises concerns about its ability to exert sufficient pressure on pest species, potentially limiting its role in biological control. To overcome this limitation, further studies are necessary to explore strategies for enhancing parasitism rates.

According to Harvey et al. (1999), various conditions affect parasitoid quality such as environmental conditions, host stages, and different host species. The pupal stage development times of *D.* (*L.*) *chasanica* varied depending not only on host species, *M. alternatus* and *A. glabripennis*. At 25 °C, the pupal stage of *D.* (*L.*) *chasanica* lasted

11.6 ± 1.9 days when parasitizing *M. alternatus* (Table 2) and 18–20 days when attacking *A. glabripennis* (Cao et al. 2019). Despite the difference in host species, the development times of *D.* (*L.*) *chasanica* were shorter when later instar larvae were attacked. Although *D.* (*L.*) *chasanica* is an idiobiont ectoparasitoid, which typically have more consistent development times across host stages, the members of *D.* (*L.*) *chasanica* exhibit a similar pattern to the koinobiont endoparasitoid. Female adults of *D.* (*L.*) *chasanica* oviposited eggs on the second and third instar larvae of *M. alternatus*, *A. glabripennis* was attacked when it was in the first instar, which could contribute to its longer development time in comparison to *M. alternatus*. Harvey et al. (1999) found that the longest development time of *Cotesia rubecula* (Marshall, 1885) (Braconidae: Microgastrinae) was observed when the first instar larvae were used as hosts, with shorter development times when later instar larvae were parasitized when attacking the earliest instar host larvae of *Pieris rapae* (Linnaeus, 1758) (Lepidoptera: Pieridae). This finding further supports the potential influence of host stage on parasitoid development times. To assess the viability of *D.* (*L.*) *chasanica* as a biological control agent, future studies should investigate which host species are more appropriate for rearing higher quality parasitoids, as well as whether a longer immature stage would contribute to the production of superior parasitoids. Additionally, a comprehensive evaluation of the various factors influencing parasitoid quality is needed to determine the optimal conditions for *D.* (*L.*) *chasanica* as a biological control agent.

There was no significant variation in parasitism rates at the 6-meter height, which *M. alternatus* favors for oviposition (Table 2) (Futai et al. 1994), compared to other heights. This lack of variation may be due to an insufficient number of samples or parasitoid flight activity. Therefore, increasing the number of study sites and surveys is necessary to further investigate the ecology of *D.* (*L.*) *chasanica* in the field.

A. glabripennis, reported as a host for *D.* (*L.*) *chasanica* in China, is also found in Korea. However, *D.* (*L.*) *chasanica* has not been reported as a natural enemy of *A. glabripennis* in Korea (Hérard et al. 2006). The genetic differences between the Korean and Chinese populations of *A. glabripennis* could potentially explain the absence of this parasitoid-host interaction in the Korean population (Kim et al. 2019; Lee et al. 2020). Another species in *Anoplophora*, *A. chinensis* (Forster, 1771) (Coleoptera, Cerambycidae) is a well-known pest of citrus trees on Jeju Island, especially from July to August (Kim et al. 2000), and is also a serious invasive species in the U.S. (Hu et al. 2009). The biology and ecology of both *A. glabripennis* and *A. chinensis* are significantly similar. This suggests that *D.* (*L.*) *chasanica* could be a valuable biological control agent for *A. chinensis*, an agricultural pest in Korea, and *A. chinensis*, an invasive species.

In this study, we presented details on the collection and rearing of *M. alternatus*, along with a re-description and biological note on the parasitoid *D.* (*L.*) *chasanica*. This is the first report of *D.* (*L.*) *chasanica* as a natural enemy of *M. alternatus* larvae. Additionally, we discussed the potential use of *D.* (*L.*) *chasanica* as a natural enemy of *A. chinensis*, *A. glabripennis* and *M. alternatus* providing foundational data for future research on biological control of the three cerambycid pest species.

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